TECHNICAL REPORT ARLCB-TR-80030

AN EXPERIMENTAL INVESTIGATION OF STRESSES IN A STEEL MODEL OF AN OVERLOADED BREECH RING BY MEANS OF PHOTOELASTIC COATING TECHNIQUE

Y. F. Cheng

August 1980

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER WEAPON SYSTEMS LABORATORY
BENÉT WEAPONS LABORATORY
WATERVLIET, N. Y. 12189

AMCMS No. 36KA7000204

DA Project No. 156401813GRN

PRON No. 1A0215641A1A

DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The use of trade name(s) and/or manufacturer(s) does not constitute an official indorsement or approval.

DISPOSITION

Destroy this report when it is no longer needed. Do not return it to the originator.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ARLCB-TR-80030	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN EXPERIMENTAL INVESTIGATION OF STRESSES IN A STEEL MODEL OF AN OVERLOADED BREECH RING BY MEANS OF PHOTOELASTIC COATING TECHNIQUE		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Y. F. Cheng		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, NY 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 36KA7000204 DA Project No. 156401813GRN PRON No. 1A0215641A1A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon Systems Laboratory Dover, NJ 07801		12. REPORT DATE August 1980 13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Breech Ring
Photoelastic Coating
Residual Stress
Stress Concentration Factor

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An experimental investigation of stresses at the lower fillet in a two dimensional steel model of an overloaded breech ring by means of photoelastic coating technique has been made. The basis of the technique is given. Expressions for stress and strain in both the elastic and elasto-plastic state are derived. Maximum fillet stress, stress concentration factor, as well as the residual stress after unloading were found. The results were compared with previous data from polycarbonate model.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

TABLES

LIST OF ILLUSTRATIONS

ACKNOWLEDGEMENT

Charles Cobb's participation in the experimental phase of this investigation is hereby acknowledged.

INTRODUCTION

In guns with a sliding breech mechanism, breech ring failures have been observed originating from the lower fillet in the vicinity of the contact region which indicates that high tensile stress produced by stress concentration at the fillet was responsible for the failure. One can reduce the stress concentration by changing the fillet geometry[1] or the breech ring can be overloaded into the plastic range to produce beneficial residual stress as long as future loadings are within the linearly elastic behavior of the material. Using a two dimensional polycarbonate model, the residual stress at the fillet of an overloaded breech ring after unloading has been determined by means of photoplasticity[2] and finite element analysis.[3]

In the two-dimensional elastic state of stress the transition of data from model to prototype requires the following conditions: equilibrium, compatibility, boundary value, and similarity of geometry and loadings. In order to make the transition involving plastic flow, at least three more conditions must be met: (a) the stress-strain curves of the materials of model and prototype must have the same shape, (b) the law of yielding must be the same for both materials, and (c) Poisson's ratio in the plastic range must be equivalent. The Poisson's ratio and the law of yielding are known

---

[1]Cheng, Y. F., "On Maximum Fillet Stresses in Breech Ring ," Watervliet Arsenal Technical Report WVT-7255, October 1972.

[2]Cheng, Y. F., "A Photoplastic Study of Residual Stress in An Overloaded Breech Ring," Technical Report ARLCB-TR-78018, Benet Weapons Laboratory, LCWSL, ARRADCOM, US Army, 1978.

[3]Chen, P. C. T. and Cheng, Y. F., "Stress Analysis of An Overloaded Breech Ring," To be presented at the International Conference on Reliability Stress Analysis and Failure Presentation, ASME, San Francisco, August 1980.

for the polycarbonate material used. Experimental data is transferable from polycarbonate model to any other material having the same value of Poisson's ratio and following the same law of yielding. The shape of the stress strain curve is represented by a parameter in the Ramberg-Osgood equation.[4] It is possible to alter the shape of the stress-strain curve of polycarbonate material by adjusting the temperature and relative humidity of the laboratory so that the curve corresponds more closely to that of a particular prototype material.

This report describes a further study on stresses at the lower fillet in a two dimensional steel model of an overloaded breech ring by means of photoelastic coating technique. The basis of the technique is given. Expressions for stress and strain in both the elastic and elastoplastic state are derived. The steel model was loaded up to more than 100% of overloading. Maximum fillet stress, stress concentration factor, as well as the residual stress after unloading were found. The results were compared with previous data from polycarbonate model. The reliability of both photoplasticity and coating technique are ascertained.

PHOTOELASTIC COATING TECHNIQUE

The photoelastic coating technique was initially introduced by Mesnager[5] in 1930. The method is based upon the bonding of a thin sheet of photoelastic material to the surface of a specimen. When load is applied to the specimen, strains are transmitted to the coating material which then becomes

---

[4]Ramberg, W. and Osgood, W. R., "Description of Stress-Strain Curves by Three Parameters," NACA TN 902, 1943.

[5]Mesnager, M., "Sur la Determination Optique des Tensions Interieures dan les Solides a Trois Dimensions," Compt. Rend. l'Acad. Sci., Vol. 190, 1249-1250, 1930.

birefringent. Polarized light is reflected from the surface of the specimen at normal incidence, and fringe patterns are obtained as in the photoelastic method. The photoelastic coating material in effect acts as a strain gage and permits the determination of the strains of the specimen over the coated area.

The fringe pattern is related to the principal strain difference, $(\varepsilon_1-\varepsilon_2)_s$, on the surface of the specimen by the following equation

$$N = 2C't(\varepsilon_1-\varepsilon_2)_s \tag{1}$$

and

$$(\varepsilon_1-\varepsilon_2)_s = (\varepsilon_1-\varepsilon_2)_p \tag{2}$$

where N denotes the fringe order, C' a strain-fringe constant, t thickness of the coating layer, and subscripts s and p refer to the specimen and coating, respectively.

The fringe pattern, therefore, directly gives the distribution of the principal strain difference on the surface of the specimen. Total strain difference, the sum of the elastic and plastic parts, are measured.

ANALYSIS OF STRESS AND STRAIN

On the surface of the specimen and the coating material, stress-strain relations are governed by Hooke's law as follows

$$(\varepsilon_1-\varepsilon_2)_s = (1+\mu_s)(\sigma_1-\sigma_2)_s/E_s \tag{3}$$

$$(\varepsilon_1-\varepsilon_2)_p = (1+\mu_p)(\sigma_1-\sigma_2)_p/E_p \tag{4}$$

where μ denotes Poisson's ratio, E Young's modulus, and σ_1 and σ_2 the principal stresses.

In the coating material, the fringe N is directly proportional to the principal stress difference $(\sigma_1-\sigma_2)_p$ by the following equation

$$N = 2Ct(\sigma_1-\sigma_2)_p \tag{5}$$

where C is the stress-fringe constant and

$$C = (1+\mu_p)(C'/E_p) \tag{6}$$

Combining equations (1) to (6), we have

$$\begin{aligned}(\sigma_1-\sigma_2)_s &= (N/2C't)[E_s/(1+\mu_s)] \\ &= (N/2C't)(E_s/E_p)[(1+\mu_p)/(1+\mu_s)] \qquad (7)\end{aligned}$$

On the free boundary one of the principal stresses is identically zero. In the elastic state the other principal stress can be readily calculated from equation (7).

In the plastic state we have

$$(\varepsilon_1-\varepsilon_2)_s = N/2C't \tag{1}$$

and

$$(\varepsilon_1+\varepsilon_2+\varepsilon_3)_s = 0 \tag{8}$$

This is not sufficient to separate individual principal strain and stress except those on the free boundary of a plane stress problem where

$$(\sigma_2)_s = (\sigma_3)_s = 0 \tag{9}$$

and

$$(\varepsilon_2)_s = (\varepsilon_3)_s = -0.5(\varepsilon_1)_s \tag{10}$$

The principal strain $(\varepsilon_1)_s$ in the specimen tangent to the free boundary becomes, from equation (1)

$$(\varepsilon_1)_s = N/3C't \tag{11}$$

The principal stress $(\sigma_1)_s$ in the specimen corresponding to the principal strain $(\varepsilon_1)_s$ can be found from the stress-strain relation for the specimen material in uniaxial tension.

EXPERIMENTS AND RESULTS

Apparatus

A portable reflection type polariscope with monochromatic light of 5461 Å was used, and photoelastic patterns at normal incidence were recorded. Static loads were applied by means of Baldwin-Tate-Emery testing machine.

Materials and Calibration

Flat ground steel plate of 0.12 inch thickness with a chemical content of 0.85 - 0.95 C, 1.00 - 1.25 Mn, 0.20 - 0.40 Si, 0.40 - 0.60 Cr, 0.40 - 0.60 W, and 0.10 - 0.20 V was used as the model material. It was supplied by Simons Saw and Steel, Fitchburg, MA (Division Wallace-Murray Corp.).

Type PS-1 photoelastic sheet of 0.04 inch thickness was used as the coating material. It was supplied by Measurement Group, Raleigh, NC.

Uniaxial tension calibration specimens of steel having a cross section of 0.19 x 0.12 inch were prepared with electric resistance wire strain gages (EA-13-015DJ-120, Micromeasurement) bonded to each specimen at its midsection, one on each side. Coating material was applied on the specimen surface.

Figure 1 shows the stress-strain curve for steel from strain gage readings. It has a Young's modulus of 30×10^6 psi, a proportional limit of 51×10^3 psi and a yielding stress σ_y, defined by the point of intersection

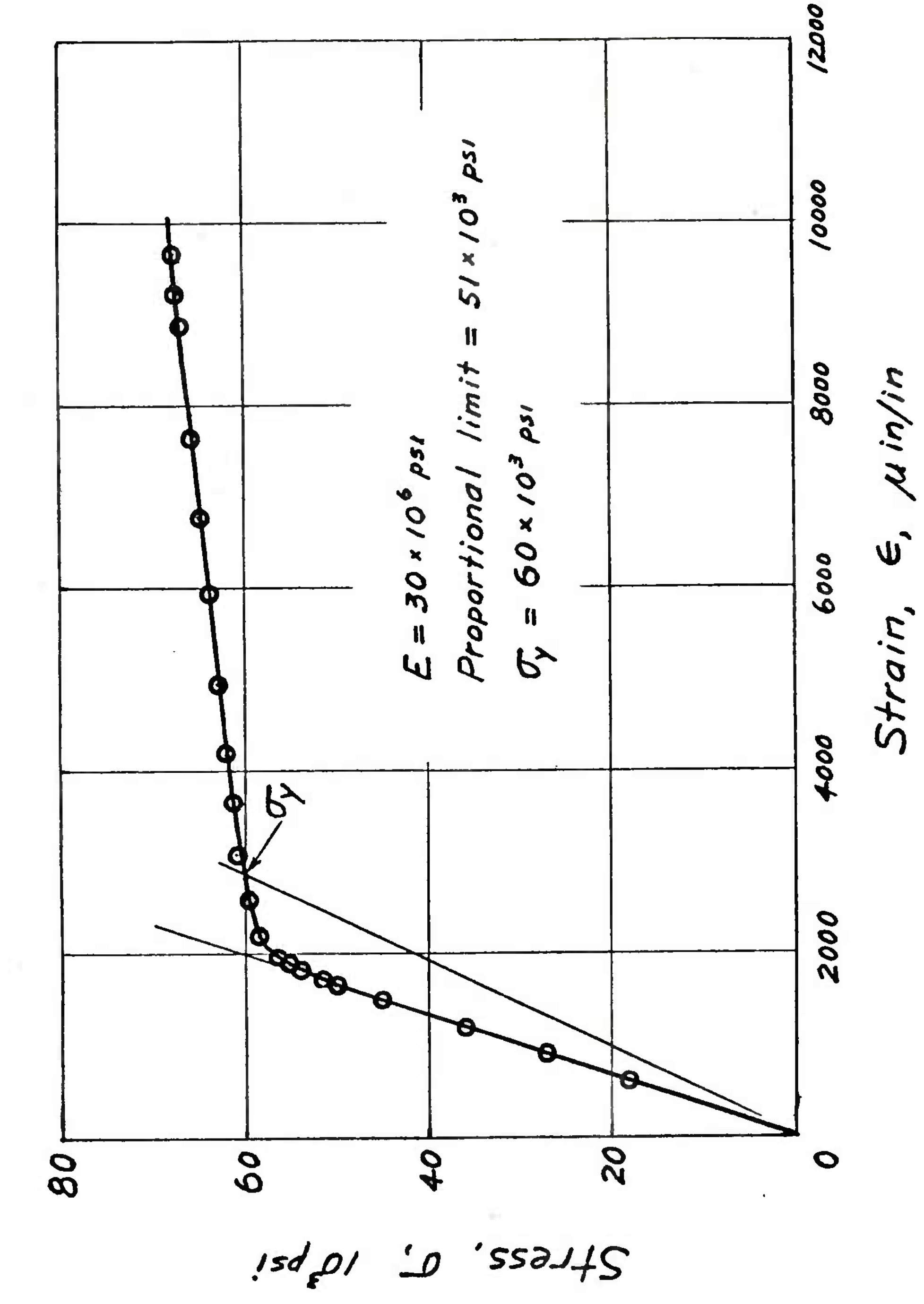

Fig. 1. Stress-Strain Curve for Steel

of secant modulus (E_{sec} = 0.7E) and the stress-strain curve, of approximately 60 x 10^3 psi. Poisson's ratio was taken to be 0.3.

The coating material registered one fringe every 1890 x 10^{-6} in/in of axial strain. In uniaxial tension

$$(\varepsilon_2)_s = -(\mu\varepsilon_1)_s = -0.3(\varepsilon_1)_s \tag{12}$$

and

$$(\varepsilon_2)_s = -570 \times 10^{-6} \text{ in/in}$$

From equation (1)

$$1/(2C't) = (\varepsilon_1-\varepsilon_2)_s = 2460 \times 10^{-6} \text{ in/in} \tag{13}$$

Model and Loading

Due to the available size of the model material, a 55/65 scale, two-dimensional model of the meridian section of a breech ring and block was made of 0.12 inch thick steel plate, as shown in Figure 2. In order to minimize any effect of material homogeneity, the ring was cut closely to the calibration specimens and its line of loading was parallel with that of the calibration specimens. Photoelastic coating material was bonded to both surfaces of the lower part of the ring. The boundary of the coating layer was carefully machined so as to coincide with the fillet. The model was mounted in the testing machine and the load was applied through pins at the top of the block and the ring.

Maximum Fillet Stress and Stress Concentration Factor in the Elastic State

The load per half-fringe order at the fillet boundary in the elastic state was found to be 2100 pounds tension, which corresponds to a principal strain difference of $(\varepsilon_1-\varepsilon_2)_s$ = 1230 x 10^{-6} in/in.

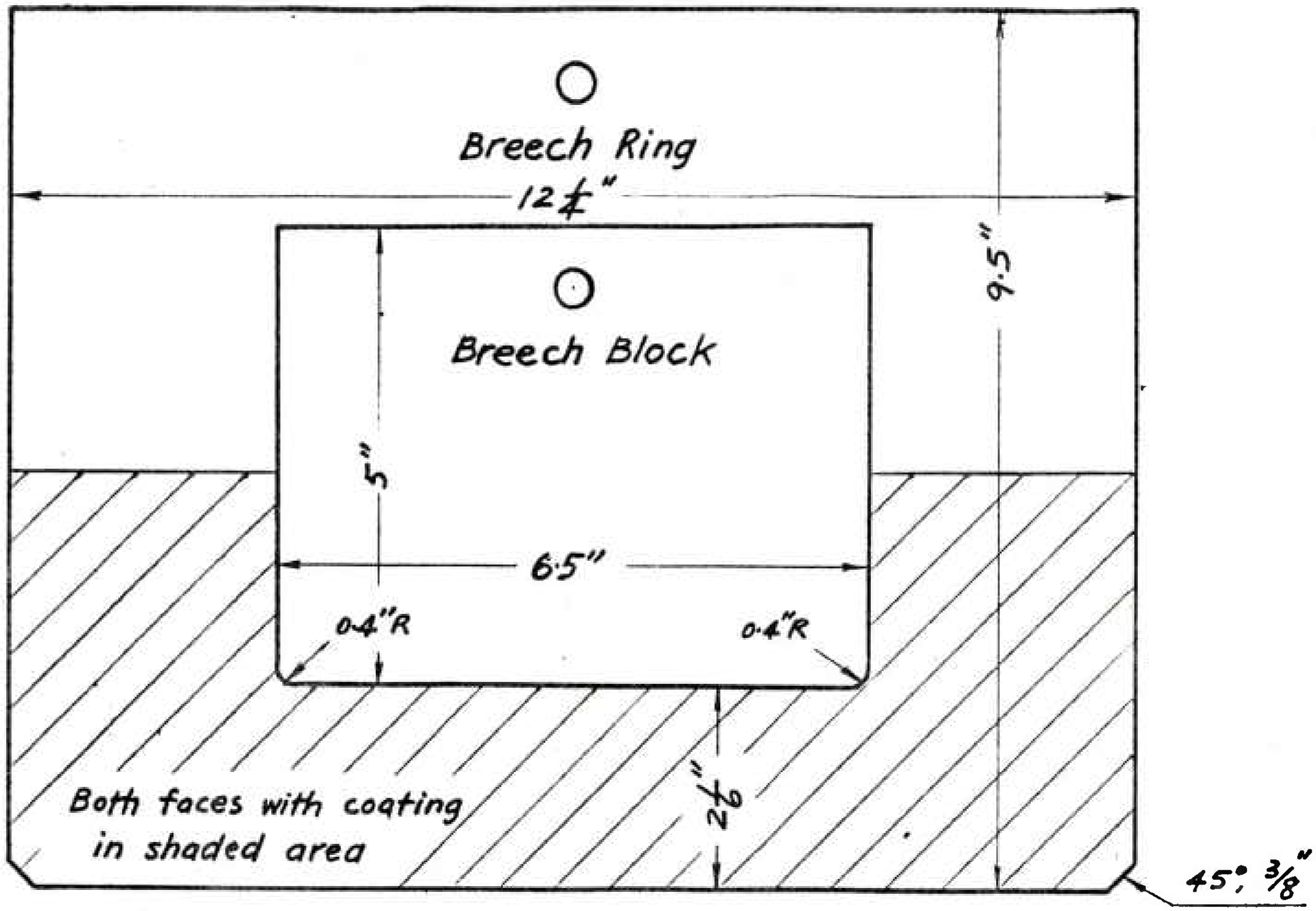

Fig. 2. Sketch of the Model

The maximum fillet stress, i.e., the maximum principal stress $(\sigma_1)_s$, tangent to the fillet boundary can be calculated from equations (7) and (13), taking into consideration of $(\sigma_2)_s = 0$. Thus

$$(\sigma_1)_s = (N/2C't)E_s/(1+\mu_s)$$
$$= (0.5)(2460)(30 \times 10^6)/1.3$$
$$= 28.4 \times 10^3 \text{ psi}$$

Alternately, it can also be obtained by means of Hooke's law. Thus, at the free boundary

$$(\varepsilon_2)_s = -(\mu\varepsilon_1)_s = -0.3(\varepsilon_1)_s \qquad (14)$$

and

$$1.3(\varepsilon_1)_s = 1230 \times 10^{-6} \text{ in/in}$$
$$(\sigma_1)_s = (E\varepsilon_1)_s = (30)(1230)/1.3 = 28.4 \times 10^3 \text{ psi}$$

The average stress σ_{av} at the cross section has a value of

$$\sigma_{av} = 2100/[(0.12)(5.75)(55/65)] = 3.60 \times 10^3 \text{ psi}$$

The stress concentration factor K, defined as the ratio between the maximum principal stress $(\sigma_1)_s$ and the average stress σ_{av}, is

$$K = (\sigma_1)_s/\sigma_{av} = 7.88$$

Maximum Fillet Stress and Stress Concentration Factor in the Elastoplastic State

After the elastic solution was obtained, the load was raised and the specimen was brought into the elastoplastic state. The load corresponding to each increasing integral fringe order was recorded. Principal strain difference $(\varepsilon_1-\varepsilon_2)_s$ and maximum principal strain $(\varepsilon_1)_s$ were calculated from equations (1), (11), and (14), considering both elastic and plastic parts.

The proportional limit stress of the specimen material has a value of 51×10^3 psi. The corresponding strain is

$$(\varepsilon_1)_s = (51 \times 10^3)/(30 \times 10^6) = 1700 \times 10^{-6} \text{ in/in}$$

From equation (14), $(\varepsilon_2)_s = -0.3(\varepsilon_1)_s$ and the elastic part of the principal strain difference is

$$(\varepsilon_1 - \varepsilon_2)_s = 1.3(\varepsilon_1)_s = 2200 \times 10^{-6} \text{ in/in}$$

The plastic part of $(\varepsilon_1)_s$ was calculated by applying equations (1) and (11) to the plastic part of principal strain difference. For example, at $P = 6000$ pounds, $(\varepsilon_1 - \varepsilon_2)_s = 4920 \times 10^{-6}$ in/in with an elastic part of 2200×10^{-6} in/in and a plastic part of 2720×10^{-6} in/in.

$$(\varepsilon_1)_{s,plastic} = (\tfrac{2}{3})(2720) = 1810 \times 10^{-6} \text{ in/in}$$

and

$$\begin{aligned}(\varepsilon_1)_{s,total} &= (\varepsilon_1)_{s,elastic} + (\varepsilon_1)_{s,plastic} \\ &= 1700 \times 10^{-6} + 1810 \times 10^{-6} \\ &= 3510 \times 10^{-6} \text{ in/in}\end{aligned}$$

The corresponding principal stress $(\sigma_1)_s$ was read from stress-strain curve, Figure 1. Average stress σ_{av} and stress concentration factor K were calculated. They are shown in Table I.

The results show that as long as the specimen is in the elastic state, stress concentration factor K is constant and the curve K versus σ_{av} is straight and horizontal. However, if σ_{av} is increased so that local yielding sets in at the point of highest stress, the stress concentration factor begins to decrease rather sharply, as shown in Figure 3.

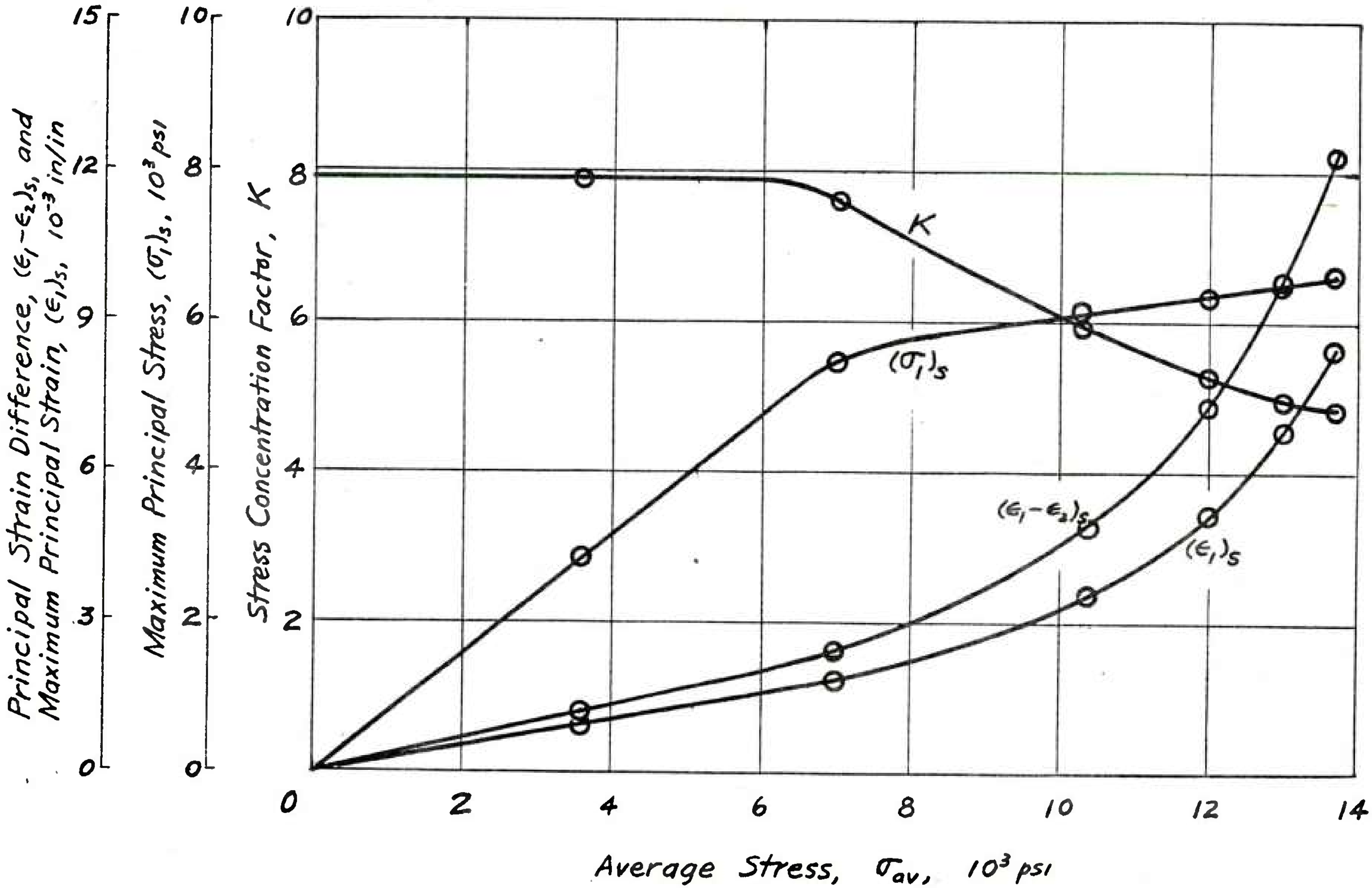

Fig. 3. Curves of Stress Concentration Factor K, Maximum Principal Stress $(\sigma_1)_s$, Principal Strain Difference $(\epsilon_1-\epsilon_2)_s$, and Maximum Principal Strain $(\epsilon_1)_s$ versus Average Stress, σ_{av}

DISCUSSIONS

Calculated Residual Stress and Percentage of Overloading

The usual assumption that unloading is inherently an elastic process is made for the purpose of calculating the residual stress after unloading. For example, in the elastic state, a load of 2100 pounds produces a fillet stress of 28.4×10^3 psi. A load of 8000 pounds would produce a fillet stress of 108.2×10^3 psi. Subtractive superposition of the value with 66.3×10^3 psi from elastoplastic state of 8000 pounds gives a residual stress of 41.9×10^3 compression, as shown in Table I.

The proportional limit load is the load which produces a fillet stress equal to the proportional limit of the material. It is used as the basis for calculating the percentage of overloading. It can be shown the proportional limit load for the specimen has a value of 3770 pounds. The percentage of overloading is defined as $\frac{P-3770}{3770} \times 100\%$.

The residual stress and percentage of overloading for five loads in the elastoplastic state were calculated and shown in Table I.

Comparison With Results Obtained Previously From Polycarbonate Model

A comparison was also made between results obtained from steel and those from polycarbonate material, Table II.

In the elastic state, stress concentration factors obtained from steel has a value of 7.88 and polycarbonate material has a value of 7.67. The difference is within the range of experimental error.

TABLE I. MAXIMUM STRESS, STRESS CONCENTRATION FACTOR, AND RESIDUAL STRESS AT THE LOWER FILLET

Load P Pounds	Fringe Order N	Principal Strain Difference $(\varepsilon_1-\varepsilon_2)_s$ in/in	Maximum Principal Strain $(\varepsilon_1)_s$ in/in	Maximum Principal Stress $(\sigma_1)_s$ psi	Average Stress σ_{av} psi	Stress Concentration Factor $K=(\sigma_1)_s/\sigma_{av}$	Percentage of Overloading (P-3770)/3770	Residual Stress psi
2100	0.5	1230×10^{-6}	950×10^{-6}	28.4×10^3	3.60×10^3	7.88	-	-
4100	1	2460×10^{-6}	1870×10^{-6}	54.9×10^3	7.02×10^3	7.63	9	-0.5×10^3
6000	2	4920×10^{-6}	3510×10^{-6}	61.2×10^3	10.3×10^3	5.96	59	-19.9×10^3
7000	3	7380×10^{-6}	5150×10^{-6}	63.1×10^3	12.0×10^3	5.26	86	-31.6×10^3
7600	4	9840×10^{-6}	6790×10^{-6}	64.7×10^3	13.0×10^3	4.97	102	-38.1×10^3
8000	5	12300×10^{-6}	8440×10^{-6}	66.3×10^3	13.7×10^3	4.84	112	-41.9×10^3

TABLE II. COMPARISON BETWEEN STEEL AND POLYCARBONATE MODEL

		Steel	Polycarbonate
	Load	2100 pounds	27 pounds
Elastic State	Maximum Fillet Stress	28.4×10^3 psi	300 psi
	Average Stress	3.6×10^3 psi	39 psi
	Stress Concentration Factor	7.88	7.67
	Load	7600 pounds	1144 pounds
Elastoplastic State	Maximum Fillet Stress	64.7×10^3 psi	9.3×10^3 psi
	Percentage of Overloading	102	105
	Average Stress	13.0×10^3 psi	1.66×10^3 psi
	Stress Concentration Factor	4.97	5.61

In the elastoplastic state, stress concentration factor obtained from steel with 102% overloading has a value of 4.97 and that from polycarbonate material with 105% overloading has a value of 5.61.

Figure 4 shows stress-strain curves of steel and polycarbonate. The fact that polycarbonate has a higher strain-hardening effect explains its high value of stress concentration factor in the elastoplastic state, although the slight difference in percentage of overloading may affect it also.

A transition formula for stresses in the elastic state was given in the previous work. It has the following form

$$\frac{\sigma_s}{\sigma_m} = \frac{P_s}{P_m}\frac{(L_m)^2}{(L_s)^2}$$

where L is the characteristic length and subscripts s and m refer to specimen and model respectively. Using this equation, under a load of 2100 pounds, the steel specimen should experience a maximum fillet stress of $(2100/27)(65/55)(300) = 27.6 \times 10^3$ psi in comparison with the experimental value of 28.4×10^3 psi. The difference is again within the range of experimental error.

In the elastoplastic state, the same equation gives the steel specimen, under a load of 7600 pounds and 102% overloading a maximum fillet stress of $(7600/1144)(65/55)(9300) = 73 \times 10^3$ psi in comparison with the experimental value of 64.7×10^3 psi. The difference can be explained by the difference in stress-strain behavior of these materials and possibly their laws of yielding, or the difference in percentage of overloading.

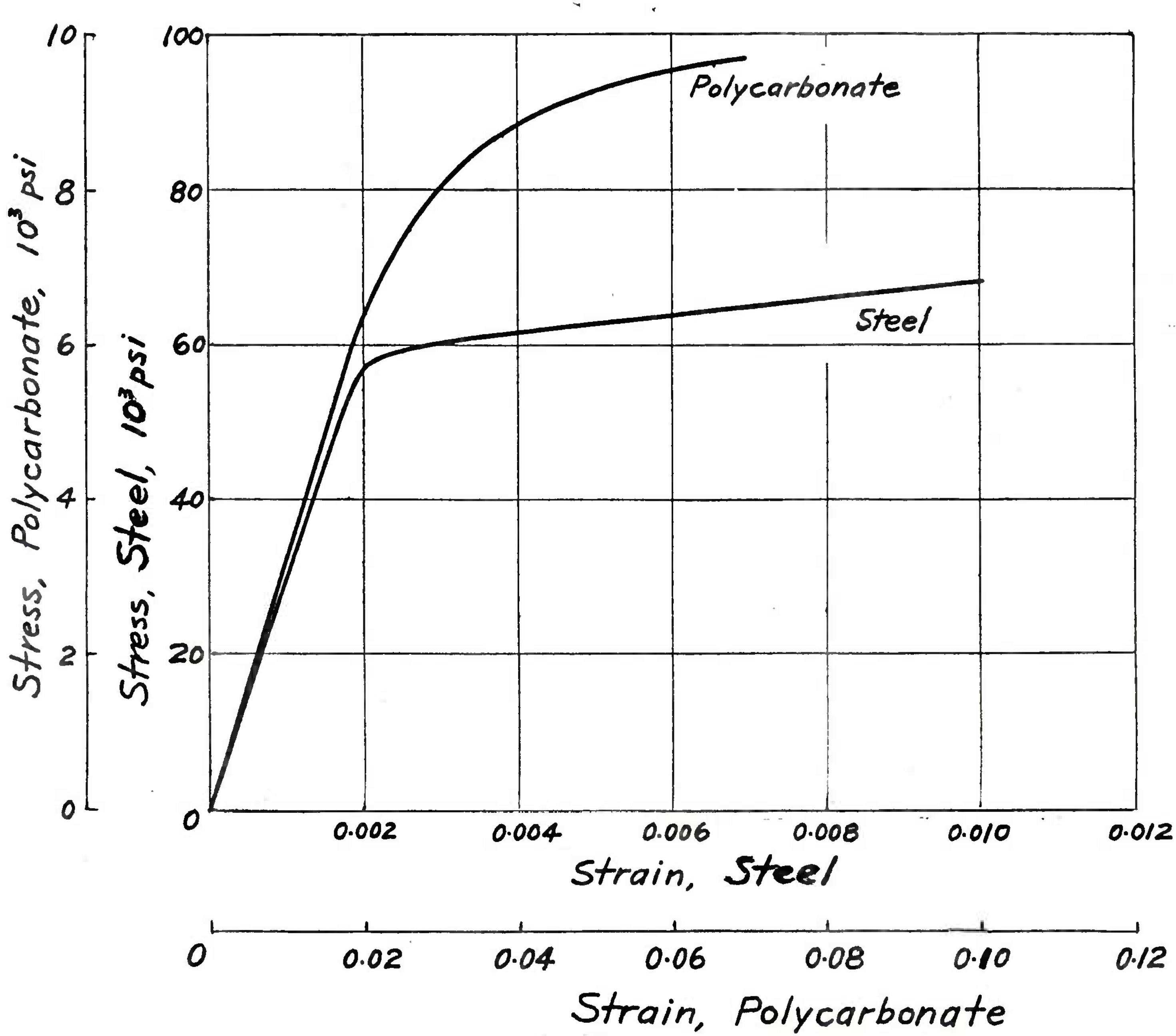

Fig. 4. Stress-Strain Curves for Polycarbonate and Steel

CONCLUSIONS

An experimental investigation of stresses in a steel model of the meridian section of a breech ring has been made by means of photoelastic coating technique.

In the elastic state, steel model has a stress concentration factor of 7.88 in comparison with 7.67 from a polycarbonate model. Also, steel model shows a maximum fillet stress of 28.4×10^3 psi from a load of 2100 pounds in comparison with 27.6×10^3 using the transition formula and data from polycarbonate model. A good agreement is established.

As stated earlier, the transition of data in the elastoplastic state requires at least three additional conditions: (a) same value of Poisson's ratio, (b) same law of yielding, and (c) same shape of stress-strain curve. Figure 4 clearly shows the violation of the last condition. Specifically, the stress-strain curves of steel and polycarbonate at room temperature do not have the same shape, although it is possible to match them closely by adjusting the temperature and relative humidity of the laboratory. Unfortunately, facilities at this laboratory do not provide for this kind of adjustment. Nevertheless, steel model with 102% overloading shows a stress concentration factor of 4.97 in comparison with 5.61 from the polycarbonate model with 105% overloading. The difference is reasonable.

The reliability of photoelastic coating technique and photoplasticity analysis have thus been confirmed in this experiment.

Now that two methods are available in studying stresses and strains in structures after yielding. One is the photoelastoplastic stress analysis provided that the laboratory is equipped with temperature and humidity controls such that the conditions for data transition from model to prototype can be met. This can not be realized, at present, due to the considerable expenses in refitting the laboratory. The alternate method is the photoelastic coating technique, described in this report, which reveals directly the stresses and strains existing on the surface of the structure.

The gun steel (typical 4330) has a considerably higher proportional limit stress in comparison with the steel used in this investigation. For the purpose of thorough understanding the stresses and strains in an overloaded breech ring, it is proposed for future work to repeat this investigation in a 4330 steel model. The results could further provide not only another evidence of the reliability of photoelastoplastic stress analysis but also the validity of data transition formula.

REFERENCES

1. Cheng, Y. F., "On Maximum Fillet Stresses in Breech Rings," Watervliet Arsenal Technical Report WVT-7255, October 1972.
2. Cheng, Y. F., "A Photoplastic Study of Residual Stress in An Overloaded Breech Ring," Technical Report ARLCB-TR-78018, Benet Weapons Laboratory, LCWSL, ARRADCOM, US Army, 1978.
3. Chen, P. C. T. and Cheng, Y. F., "Stress Analysis of An Overloaded Breech Ring," to be presented at the International Conference on Reliability Stress Analysis and Failure Presentation, ASME, San Francisco, August 1980.
4. Ramberg, W. and Osgood, W. R., "Description of Stress-Strain Curves by Three Parameters," NACA TN 902, 1943.
5. Mesnager, M., "Sur la Determination Optique des Tensions Interieures dans les Solides a Trois Dimensions," Compt. Rend. l'Acad. Sci., Vol. 190, pp. 1249-1250, 1930.

TECHNICAL REPORT INTERNAL DISTRIBUTION LIST

	NO. OF COPIES
COMMANDER	1
CHIEF, DEVELOPMENT ENGINEERING BRANCH	1
ATTN: DRDAR-LCB-DA	1
-DM	1
-DP	1
-DR	1
-DS	1
-DC	1
CHIEF, ENGINEERING SUPPORT BRANCH	1
ATTN: DRDAR-LCB-SE	1
-SA	1
CHIEF, RESEARCH BRANCH	2
ATTN: DRDAR-LCB-RA	1
-RC	1
-RM	1
-RP	1
CHIEF, LWC MORTAR SYS. OFC.	1
ATTN: DRDAR-LCB-M	1
CHIEF, IMP. 81MM MORTAR OFC.	1
ATTN: DRDAR-LCB-I	1
TECHNICAL LIBRARY ATTN: DRDAR-LCB-TL	5
TECHNICAL PUBLICATIONS & EDITING UNIT ATTN: DRDAR-LCB-TL	2
DIRECTOR, OPERATIONS DIRECTORATE	1
DIRECTOR, PROCUREMENT DIRECTORATE	1
DIRECTOR, PRODUCE ASSURANCE DIRECTORATE	1

NOTE: PLEASE NOTIFY ASSOC. DIRECTOR, BENET WEAPONS LABORATORY, ATTN: DRDAR-LCB-TL, OF ANY REQUIRED CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST

	NO. OF COPIES
ASST SEC OF THE ARMY RESEARCH & DEVELOPMENT ATTN: DEP FOR SCI & TECH THE PENTAGON WASHINGTON, D.C. 20315	1
COMMANDER US ARMY MAT DEV & READ. COMD ATTN: DRCDE 5001 EISENHOWER AVE ALEXANDRIA, VA 22333	1
COMMANDER US ARMY ARRADCOM ATTN: DRDAR-LC	1
-LCA (PLASTICS TECH EVAL CEN)	1
-LCE	1
-LCM	1
-LCS	1
-LCW	1
-TSS(STINFO) DOVER, NJ 07801	2
COMMANDER US ARMY ARRCOM ATTN: DRSAR-LEP-L ROCK ISLAND ARSENAL ROCK ISLAND, IL 61299	1
DIRECTOR US Army Ballistic Research Laboratory ATTN: DRDAR-TSB-S (STINFO) ABERDEEN PROVING GROUND, MD 21005	1
COMMANDER US ARMY ELECTRONICS COMD ATTN: TECH LIB FT MONMOUTH, NJ 07703	1
COMMANDER US ARMY MOBILITY EQUIP R&D COMD ATTN: TECH LIB FT BELVOIR, VA 22060	1
COMMANDER US ARMY TANK-AUTMV R&D COMD ATTN: TECH LIB - DRDTA-UL	1
MAT LAB - DRDTA-RK WARREN MICHIGAN 48090	1
COMMANDER US MILITARY ACADEMY ATTN: CHMN, MECH ENGR DEPT WEST POINT, NY 10996	1
COMMANDER REDSTONE ARSENAL ATTN: DRSMI-RB	2
-RRS	1
-RSM ALABAMA 35809	1
COMMANDER ROCK ISLAND ARSENAL ATTN: SARRI-ENM (MAT SCI DIV) ROCK ISLAND, IL 61202	1
COMMANDER HQ, US ARMY AVN SCH ATTN: OFC OF THE LIBRARIAN FT RUCKER, ALABAMA 36362	1
COMMANDER US ARMY FGN SCIENCE & TECH CEN ATTN: DRXST-SD 220 7TH STREET, N.E. CHARLOTTESVILLE, VA 22901	1
COMMANDER US ARMY MATERIALS & MECHANICS RESEARCH CENTER ATTN: TECH LIB - DRXMR-PL WATERTOWN, MASS 02172	2

NOTE: PLEASE NOTIFY COMMANDER, ARRADCOM, ATTN: BENET WEAPONS LABORATORY, DRDAR-LCB-TL, WATERVLIET ARSENAL, WATERVLIET, N.Y. 12189, OF ANY REQUIRED CHANGES.

TECHNICAL REPORT EXTERNAL DISTRIBUTION LIST (CONT)

	NO. OF COPIES
COMMANDER US ARMY RESEARCH OFFICE P.O. BOX 12211 RESEARCH TRIANGLE PARK, NC 27709	1
COMMANDER US ARMY HARRY DIAMOND LAB ATTN: TECH LIB 2800 POWDER MILL ROAD ADELPHIA, MD 20783	1
DIRECTOR US ARMY INDUSTRIAL BASE ENG ACT ATTN: DRXPE-MT ROCK ISLAND, IL 61201	1
CHIEF, MATERIALS BRANCH US ARMY R&S GROUP, EUR BOX 65, FPO N.Y. 09510	1
COMMANDER NAVAL SURFACE WEAPONS CEN ATTN: CHIEF, MAT SCIENCE DIV DAHLGREN, VA 22448	1
DIRECTOR US NAVAL RESEARCH LAB ATTN: DIR, MECH DIV CODE 26-27 (DOC LIB) WASHINGTON, D. C. 20375	 1 1
NASA SCIENTIFIC & TECH INFO FAC P. O. BOX 8757, ATTN: ACQ BR BALTIMORE/WASHINGTON INTL AIRPORT MARYLAND 21240	1

	NO. OF COPIES
COMMANDER DEFENSE TECHNICAL INFO CENTER ATTN: DTIA-TCA CAMERON STATION ALEXANDRIA, VA 22314	12
METALS & CERAMICS INFO CEN BATTELLE COLUMBUS LAB 505 KING AVE COLUMBUS, OHIO 43201	1
MECHANICAL PROPERTIES DATA CTR BATTELLE COLUMBUS LAB 505 KING AVE COLUMBUS, OHIO 43201	1
MATERIEL SYSTEMS ANALYSIS ACTV ATTN: DRXSY-MP ABERDEEN PROVING GROUND MARYLAND 21005	1

NOTE: PLEASE NOTIFY COMMANDER, ARRADCOM, ATTN: BENET WEAPONS LABORATORY, DRDAR-LCB-TL, WATERVLIET ARSENAL, WATERVLIET, N.Y. 12189, OF ANY REQUIRED CHANGES.